Astro-particle theory

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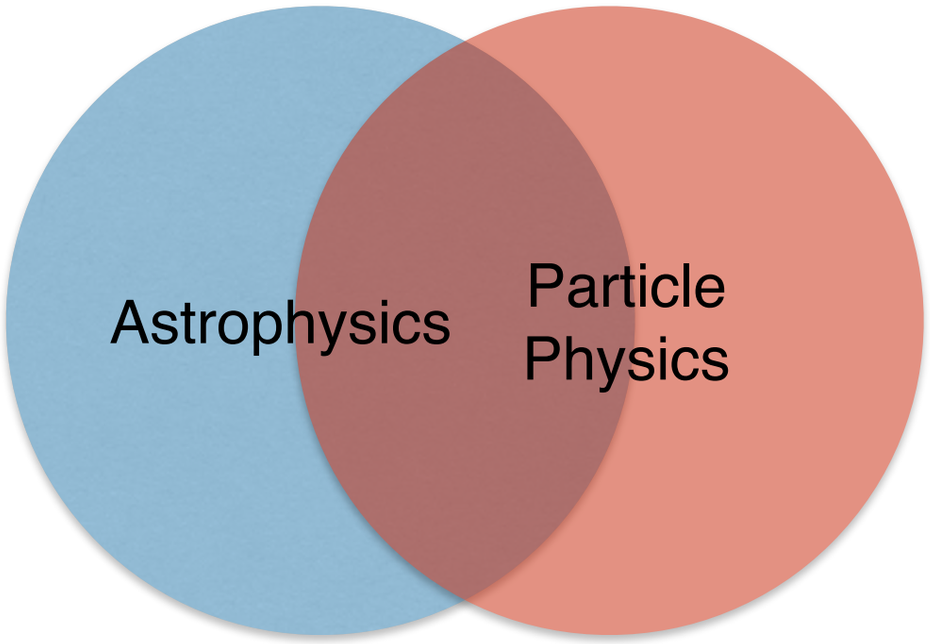
Astro-particle physics is an emerging field at the interface between astrophysics and particle physics.



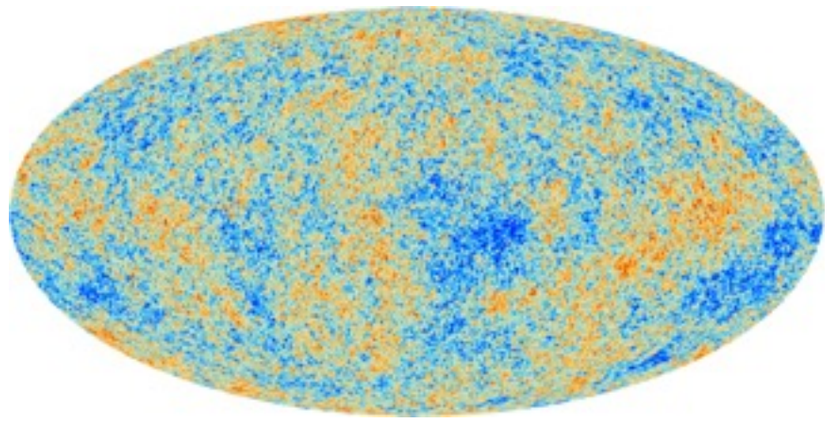
UK astro-particle theory community is small-ish but growing.

Difficult to quantify size (different people have different definitions of astro-particle physics, in particular re. overlap with early Universe cosmology).

STFC Science Roadmap Challenges

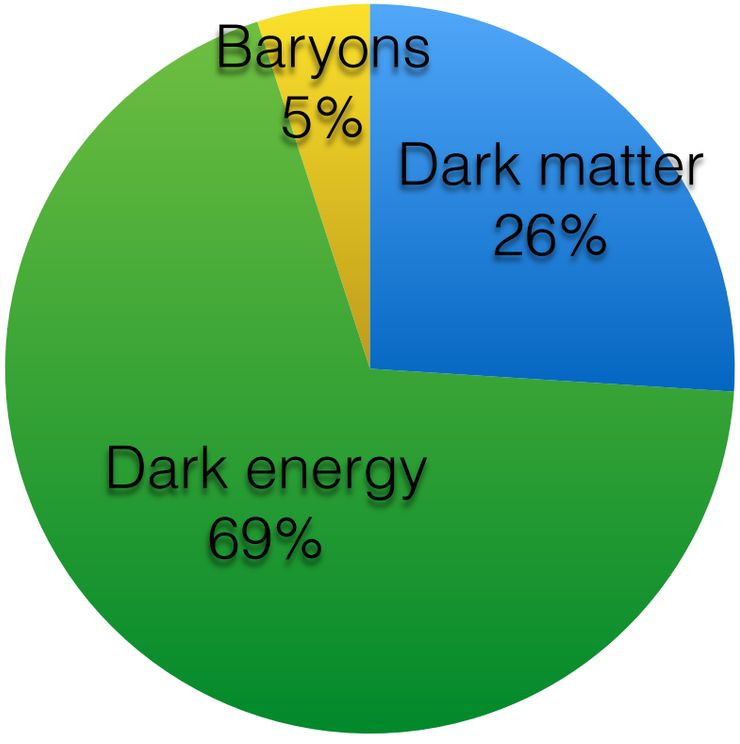
A) How did the Universe begin and how is it evolving?

1) What is the physics of the early Universe?
2) How did structure first form?
3) What are the roles of dark matter and dark energy?



C) What are the fundamental constituents and fabric of the Universe and how do they interact?

4) What is the nature of dark matter?
5) What is the nature of dark energy?



Planck

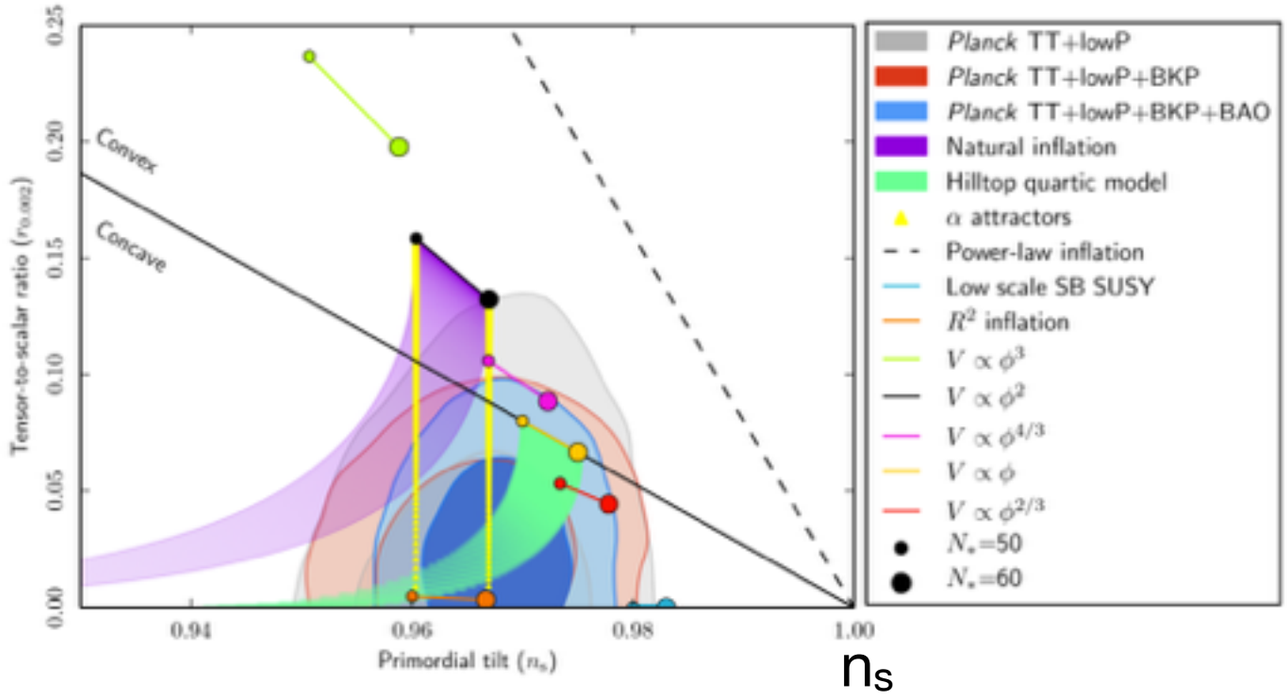
Early Universe Cosmology

What generated the primordial fluctuations from which structures form?

Possibly **inflation**, a period of accelerated expansion in early Universe, driven by a scalar field.

Planck constraints on the spectral index, $\mathbf{n_s}$, & tensor-to-scalar ratio, **r**, compared with model predictions:

r



n_s

model building

constraints from future observations (B-mode polarisation)

Also: formation, evolution & observational signatures of topological defects

phase transitions

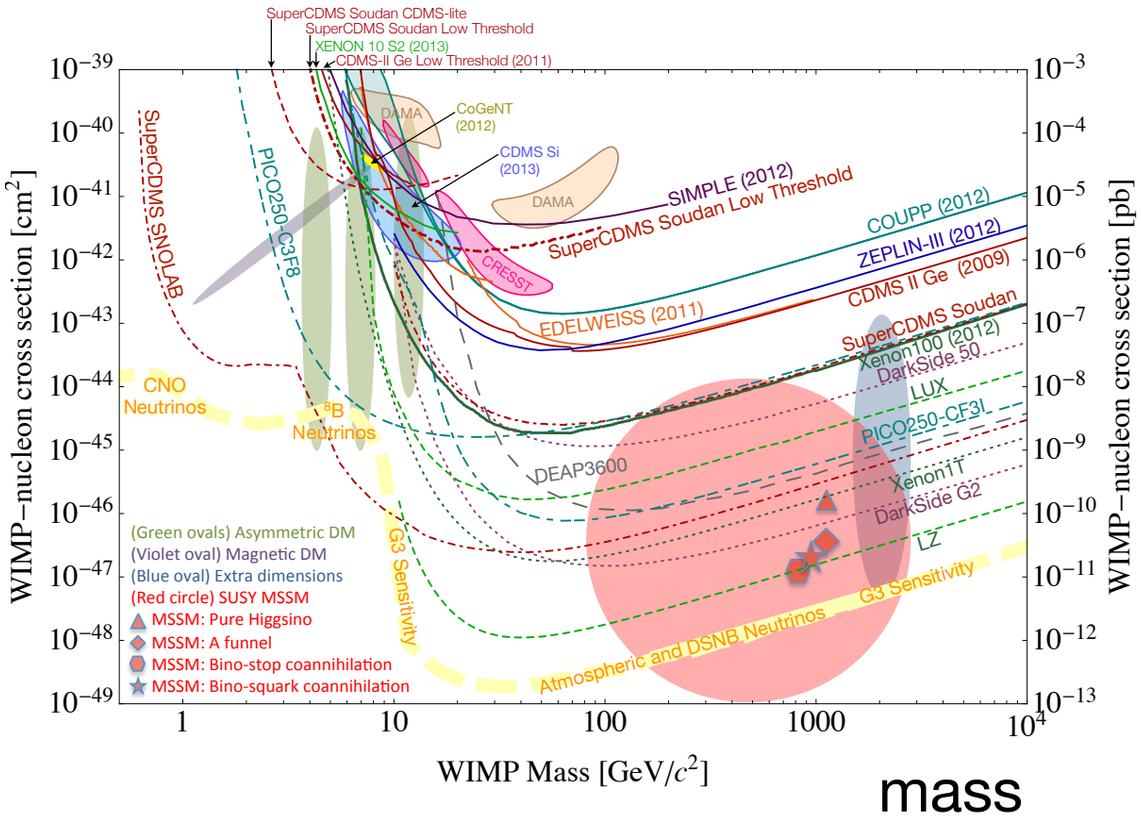
Dark Matter

Weakly Interacting Massive Particles (WIMPs) are a well-motivated dark matter candidate.

Can be detected directly in lab e.g. LZ, or indirectly via annihilation products (inc. gamma-rays) e.g. CTA.

Direct detection

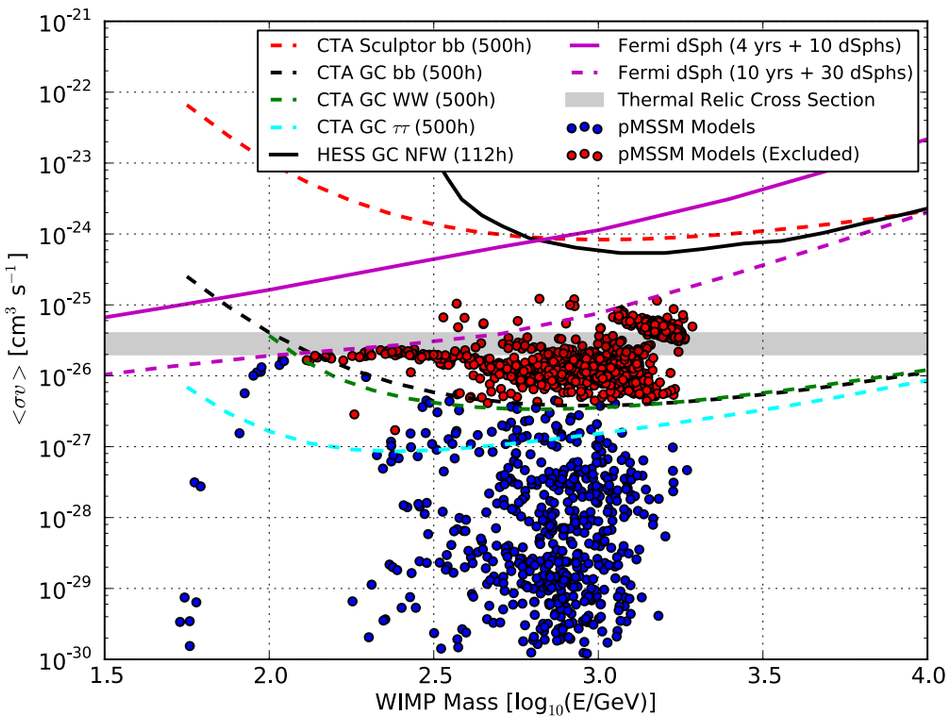
σ_{SI}



mass

gamma-rays

σ_A



mass

dark matter candidates theory/phenomenology

signals & dependence on DM distribution

Also: signatures of Axions (& ALPs) in these & other experiments/observations.

Dark Energy

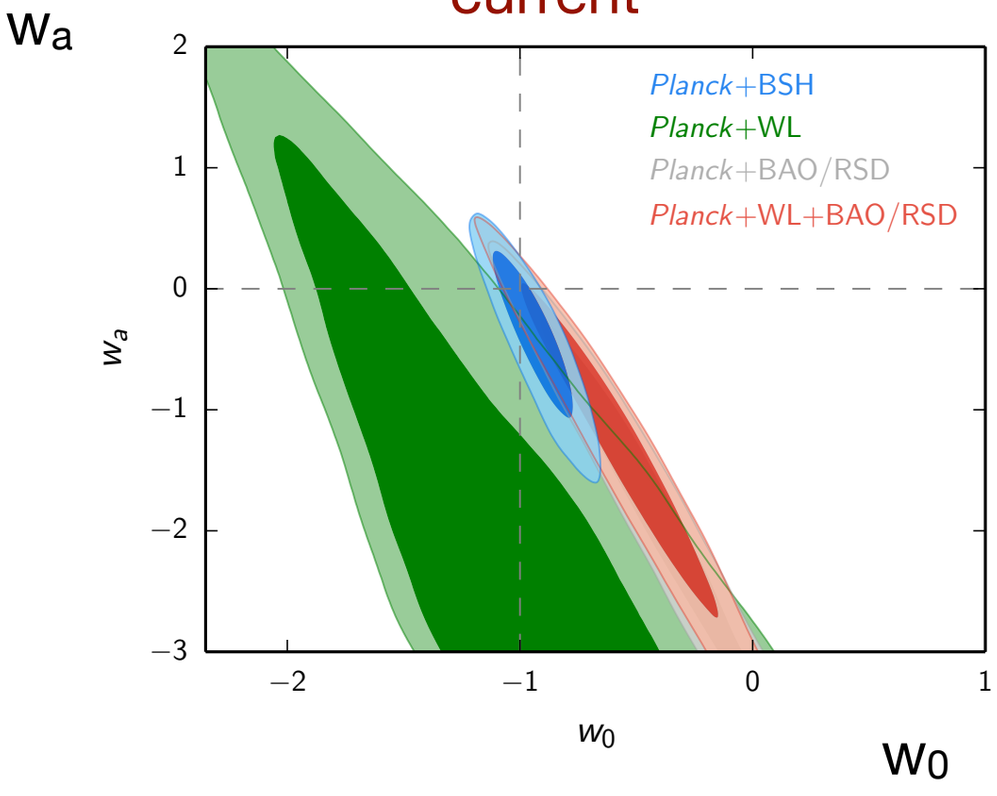
What is responsible for the present day accelerated expansion of the Universe?

a scalar field? a modification of the laws of gravity? something else?

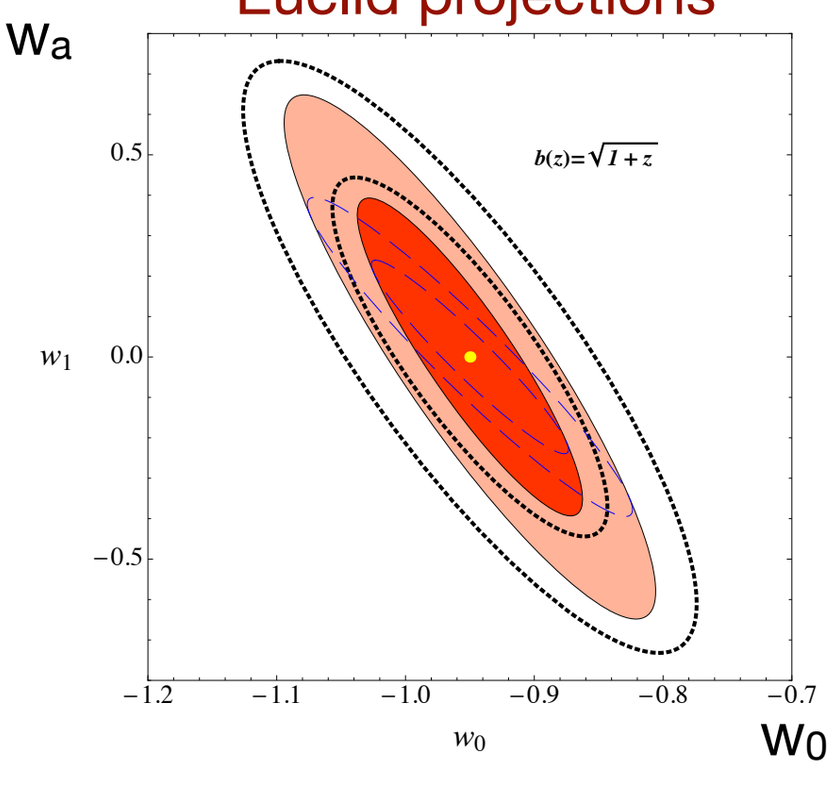
Probe dark energy by measuring the expansion rate of the Universe & the growth of perturbations. e.g. Euclid

Constraints on simple DE equation of state (p=w ρ) parameterisation: $w(a) = w_0 + (1-a)w_a$

current



Euclid projections



model building

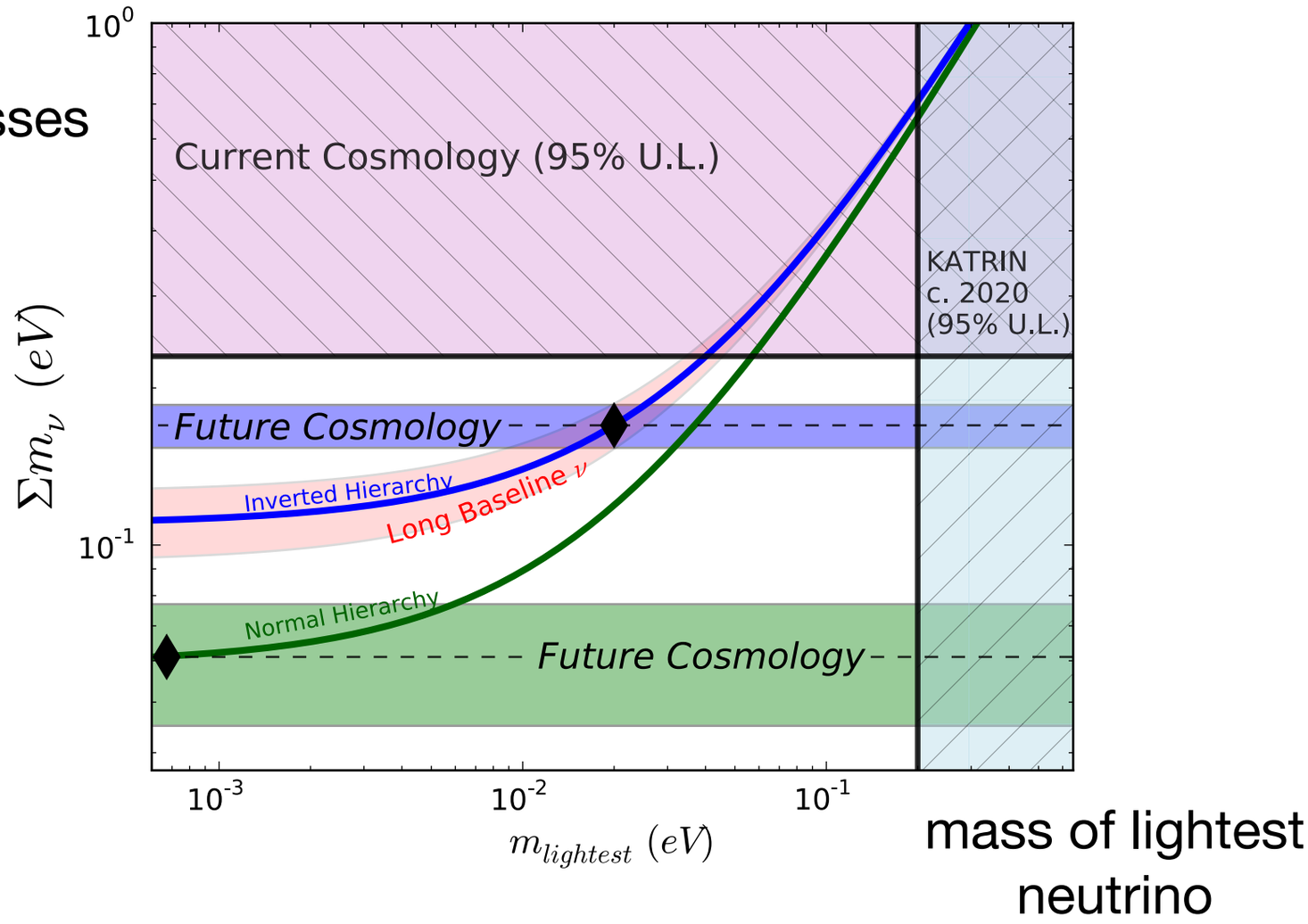
parameterisations for data comparison

Neutrinos

Constraining the neutrino masses (& hierarchy) via their effects on the CMB and structure formation.

Projected future constraints from DESI (dark energy spectroscopic instrument) + CMB polarisation:

sum of neutrino masses



mass of lightest neutrino

Snowmass Dark Energy & CMB working group